Identification of kinematics understanding of physics students at the university in coastal area

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Abstract. The phenomena of kinematics are a physics concept that is close to the daily life of students. However, most students do not realize this and often ignore it. As a result, when testing their understanding of kinematics using contextual examples (cases in the coastal area), it shows that many students have low achievements. Several studies have been carried out regarding students' understanding of kinematics. However, there is still limited identification of kinematics understanding of physics students at the university in coastal area. This study purposed to discover the conceptual understanding of the kinematics of physics students in a public university. This research was a descriptive survey that involved 129 physics students in the department of physics at Universitas Negeri Padang who tested using kinematics questions. The data obtained was analysed quantitative-descriptive. The results showed that about 26% of students have good understanding of kinematics, 6% of students have misconceptions, and 68% of students have no understanding. In conclusion, physics students still struggle to solve kinematics problems, particularly in identifying motion through a graph.

1 Introduction

Understanding the concept is one of the abilities that must be possessed by prospective physics teacher. A good understanding of concepts can help to understand a problem, identify the basic principles used to solve the problem [1], and find the relationship between the variables presented in the problem [2]. Understanding this concept will be the basis for solving physics problems presented in learning [3][4][5]. Encouraging students to implement their basic understanding of physics to recognize novel situations and develop strong problem-solving abilities is one of the goals of physics learning [5].

Achieving these learning objectives are often hampered because students' understanding of the initial concepts before learning contradicts to the scientific concepts [3]. This incorrect understanding of concepts is too strong and difficult to change to the correct one [6]. Therefore, teachers need to be able to teach various concepts by using several

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representation formats to reduce conceptual errors that occur in students [7], particularly in physics learning.

One of the physics subjects taught using a variety of representations is kinematics. In university-level general physics courses or lectures on fundamental physics, kinematics is a fundamental concept [8]. Kinematics phenomena often happen around students, but they still have difficulty understanding what concepts are involved in it. For example, many students still have difficulty understanding the concept of velocity [9], acceleration [10], the difference between distance and displacement [11], and differentiate between velocity and acceleration [10]. All difficulties have impact on students' ability to comprehend others concepts in physics, excluding kinematics. For example, a number of studies examined how well students understood the relationship between the direction of force that occurs, speed, and acceleration. The findings indicated that there are misconceptions among the students [12][13].

Kinematics problems are frequently given graphically and are intended to serve as an initial evaluation to identify the most appropriate teaching approach for the topic at hand. Previous studies have shown that addressing kinematics issues represented as graphs presents a variety of challenges. For instance, determining the type of motion of objects based on position-time, velocity-time, or acceleration-time graphs [14][15], or reading the data obtained in a diagram to determine the object's final position, velocity, and acceleration. All problems were presented due to a lack of understanding of the concept of kinematics [2][8] and mathematical operations skills used to solve problems [16].

Understanding the correct and appropriate concepts must be owned by prospective physics teachers. According to Tighe and Wiggins [17], understanding can be demonstrated through a combination of the following six abilities, namely explanation, interpretation, application, perspective, empathy, and self-reflection. Meanwhile, students' level of conceptual understanding can be categorized into No understanding [NU], Misconception [M], and Sound Understanding [SU] [18]. As a future physics teachers, they should have ability to understand physics concepts.

In summary, it is necessary to detect students understanding of physics concepts, particularly on kinematics. Even though several studies have demonstrated that students still struggle substantially in understanding kinematics concepts, it is nevertheless advised that this understanding be identified, especially with relation to the most basic concept [19]–[21]. Research findings will be basis for teacher in deciding the right strategy to teach these concepts. The purpose of this study is to determine how well university physics students in the coastal area conceptualize kinematics problems.

2 Method

This study describes the survey method used at the Department of Physics Universitas Negeri Padang (UNP). UNP is one of the universities in the coastal area in Sumatra. The population of the research was physics student who involved in 2019-2022, and this study participated 129 physics students in the Physics Education Study Program. The test instrument developed was adapted from the Test of Understanding Graphs in Kinematics (TUG-K) instrument by Beichner [22], which was tested on students who had taken the Basic Physics 1 course. It found that the kinematics test instrument was reliable, with a coefficient of 0.876. The kinematics problems given to students are related to physics cases that occur in coastal areas. With the aim of students have better understanding to the problems that will be solved because they relate to the area, they live in.

The test instrument consists of 5 multiple choice questions [number of options A-E] followed by reasons for the answers. The purpose of the questions on the test is to determine how well students understand the kinematics of the object motion graph, which includes the objects' position, displacement, distance, velocity, and acceleration. The indicator questions from the test used are shown in Table 1.

Table 1. Indicators of question given in the test

Indicators	Number of Questions
Interpreting the motion of objects through graphs of a-t, v-t, and s-t	1,2
Determining the velocity and acceleration of an object using a graph	3
Inferencing the motion of objects through illustration	4
Determining the position, displacement, and distance of objects using graphs	5

The answers given by the students were grouped based on the patterns found, analysed, and then described to report the extent of understanding the kinematics of the physics students in the Basic Physics 1 course.

3 Result and Discussion

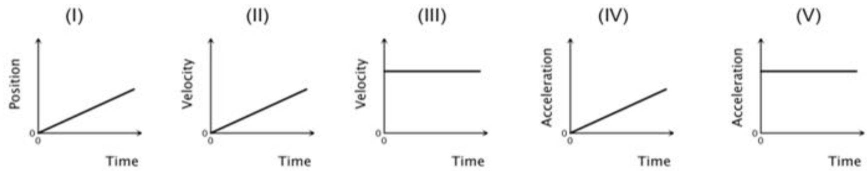
Three patterns of student responses—right answer with correct explanation, correct answer with erroneous reason, and incorrect answer with incorrect reason—were identified based on the answers provided to all of the questions. As indicated by the question's indicators, the following describes how well the student’s understood kinematics.

3.1. Interpreting the motion of objects through graphs of a-t, v-t, and s-t

Questions number one and two were used to test students' understanding of how to interpret acceleration-time [a-t], velocity-time [v-t], and position-time [s-t] graphs to illustrate the motion of objects. Students were required to choose the graph that best represented an object moving with a constant velocity in both problems, as well as the graph's interpretation of the object's motion. In Figure 1, examples for questions 1 and 2 are presented.

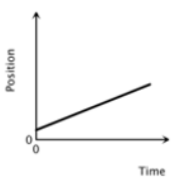
1. Consider the airplane taking off from a moving aircraft carrier (see Figure).

The plane must reach its takeoff speed before it comes to the end of the carrier's runway. If the plane starts from rest, the correct velocity-time graph representing the plane's motion with constant velocity is shown in figure number …



A. (I), (II), and (IV)
B. (I) and (III)
C. (III)
D. (III) and (V)
E. (I), (III), and (V)

2. To the below is a position versus time graph of a speedboat's motion in the sea. Which sentence is the best interpretation of the motion ?



A. The speedboat is moving with a constant, non-zero acceleration
B. The speedboat does not move
C. The speedboad is moving with a uniformly increasing celocity
D. The speedboat is moving with a constant velocity
E. The speedboat is moving with a uniformly increasing acceleration

Fig. 1. Problems of interpreting the motion of objects based on graphs

Based on students' answers to questions number 1 and 2, it identified three patterns of responses. The classification of patterns is seen from students' answer and their reasons. The grouping of answer patterns for both questions is presented in Table 2.

Table 2. Categories of students' response for question number 1 dan 2

No.	Categories	Question number 1 [Answer key: B]		Question number 2 [Answer key: D]	
		Number of respondents	Percentage	Number of respondents	Percentage
1	Correct answer-correct reason	52	40%	22	16.67%
2	Correct answer-incorrect reason	0	0	13	10%
3	Incorrect answer-incorrect	77	60%	94	73.33%

No.	Categories	Question number 1 [Answer key: B]		Question number 2 [Answer key: D]	
		Number of respondents	Percentage	Number of respondents	Percentage
	reason				

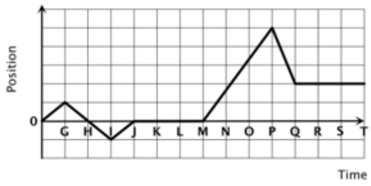
In answering question number one, students must understand the concept of velocity. Table 2 showed that only 40% of students gave the correct answer, and 60% still had the wrong answer. For students who answered the question correctly already understood velocity. Velocity is the change of an object's position per interval of time [23]. From the graphs given on the problem, picture [I] was an s-t graph that illustrates the uniform change of position of an object during the time interval, and picture [III] was a v-t graph that depicts the constant velocity that forms the straight line. For most of the wrong answers, students chose option D to determine the best interpretation of the object's motion with constant velocity. The reason for choosing the answer is based on a graph shown by a straight line. A straight line on the graph is assumed that the object is moving at a constant velocity [24]. Students primarily focused on the straight line drawn on the graph and paid less attention to the type of graph that was being presented. According to McDermott, et al., students hard to distinguish the position, velocity, and acceleration graphs [25]. Students alson have difficulty in representing contanst acceleration on a-t graph.

For question number 2, only twenty two students answered the question correctly. There were thirteen students who answered correctly with the wrong reasons, and ninety-four students answered incorrectly. From the answer and reasons given by the twenty two students, it was identified that student responses are based on the argument that the s-t graph illustrates the constant slope. According to Wemyss and van Kampen, determining an object's motion with constant velocity through a graph only depends on whether the graph shows a straight line or that the slope is constant [26]. In this case, three students were able to give the correct response to the question, but their argument was wrong. Although an object moving at a constant velocity, the student claimed that an object experienced acceleration. When an object moves at a constant velocity, there is no acceleration [24]. The remaining students who gave wrong answers selected option C because the graph's line form indicates that the object moved with uniformly increased velocity. Students found it difficult to relate the graph to the actual world because of this issue, especially when it came to using a continuous line to illustrate continuous motion [25].

3.2. Determining the velocity and acceleration of an object using a graph

The third question asked students to identify the motion of an object with the most negative velocity on a position-time [s-t] graph. The question was to assess the students' understanding of determining velocity from a graph. In Figure 2, a sample of question number three is shown.

3. One day a ship want to go to the island from the harbour. The ship is moving in a straight line and the moves show as the graph below. Which of the following options corresponds to the case of when its velocity is the most negative?



A. P to Q
B. I
C. M to P
D. G to I
E. P

Fig. 2. The problem of determining the velocity of an object based on a graph

Based on students' answers to questions number 3, it identified two patterns of responses. The classification of patterns is seen from students' answer and their reasons. The grouping of answer patterns for questions Number 3 is presented in Table 3.

Table 3. Categories of students' response for question number 3

No	Categories	Question number 3 [Answer key: A]	
		Number of respondents	Percentage
1	Correct answer-correct reason	60	46.67%
2	Incorrect answer-incorrect reason	69	53.33%

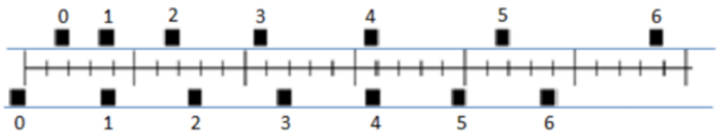
A total of 46.67% of students answered the question correctly. Students had an understanding how to determine velocity through the s-t graph. Most of them use the equation $\left(v = {}^{\Delta s}/_{\Delta t}\right)$ to prove the most negative velocity. The reason why students answered this question incorrectly was because they were unable to distinguish between a graph where the line moves to the negative y-axis and one where the line is on the positive y-axis. The results showed that students had difficulty differentiating among different motion types for an object when presented with a graph that had a negative velocity [27].

Goldberg et al. discovered that students only consider graphical representations of velocity, not the graphical representation of speed [28]. A large number of students ignored the directions. In summary, these are some opinions that students have about this issue. Students only understand the magnitude of velocity, or speed, even though they are aware that velocity is a vector unit having magnitude and direction. Due to the frequent use of this term, students consider direction and magnitude to be entirely separate components that cannot be combined into a single graphical representation. Students often struggle with negative velocity because they do not think that velocity can be lower than zero. A object may only have two possible states: moving or at rest; it cannot move in the other direction – negative direction.

3.3. Inferencing the motion of objects through illustration

Question number 4, students were asked to conclude the movement of objects from the illustrations presented. Students were asked to determine at what time two objects have the same velocity from the picture given. Question number 4 is presented in Figure 3.

4. Two speedboats move to the right in a straigline. The position of the two speedboats is observed simultaneously for six units of time and the results are shown in the figure. Zero indicates when the obeservation started.



Have the two speedboats had the same velocity?

A. Never
B. Yes, at t=1
C. Yes, at t=4
D. Yes, at t=1 and t=4
E. Yes, at some point in the time interval between t=2 and t=3

Fig. 3. The problem of determining the velocity based on the illustration

Based on students' answers to questions Number 4, it identified three patterns of responses. The classification of patterns is seen from students' answer and their reasons. The grouping of answer patterns for questions Number 4 is presented in Table 4.

Table 4. Categories of students' response for question number 4

No	Categories	Question number 4 [Answer key: E]	
		Number of respondents	Percentage
1	Correct answer-correct reason	21	16.67%
2	Correct answer-incorrect reason	26	20%
3	Incorrect answer-incorrect reason	82	63.33%

In measuring the object's velocity from the position-time diagram, the student's choice of answer is dominated by D's option. A total of 16.67% of students gave the correct answer and reason, while 63.33% were not. However, 20% of students were able to give the correct answer, but their reason was incorrect. Even though twenty-six students selected the right answer, only twenty-one of them provided the right reason, which was that since the object experienced the same displacement in the interval of 2 to 3 seconds, its average velocity was also the same during that time. This indicates that students' understanding of average velocity is still not very strong, so they cannot give reasons correctly when facing problems [29]. Students who select option D [wrong answer] believed that because the objects are in the same position, their velocities are the same. This shows that many students still think about velocity as a position per unit of time [29].

3.4. Determining the position, displacement, and distance of objects using graphs

Question number 5 presented a v-t graph, and students determine how the distance traveled by an object during the time interval. Question number 5 aims to see the ability to read data from the diagram. Figure 4 presents question number 5.

5. An elevator moves from the basement to the tenth floor of a building. The mass of the elevator is 1000 kg and it moves as shown in the velocity-time graph below.

How far does it move during the first three seconds of motion?
A. 0,75 m
B. 1,33 m
C. 4 m
D. 6 m
E. 12 m

Fig. 4. Problem of determining distance based on v-t graph

Based on students' answers to questions Number 5, it identified two patterns of responses. The classification of patterns is seen from students' answer and their reasons. The grouping of answer patterns for questions Number 5 is presented in Table 5.

Table 5. Categories of students' response for question number 5

No	Categories	Question number 5 [Answer key: D]	
		Number of respondents	**Percentage**
1	Correct answer-correct reason	13	10%
2	Incorrect answer-incorrect reason	116	90%

From the data above, it appears that 13 [10%] students chose option D [correct answer], while the remaining 116 students [90%] choose option B. Three students who answered correctly gave reasons that $\vec{v} = \frac{\Delta\vec{x}}{\Delta t}$ and determining $\Delta\vec{x}$ by calculating the area bounded by the curve at the time interval 0-3 seconds on the v-t graph. Meanwhile, 116 students who answered incorrectly gave the reason that $s = \frac{\vec{v}}{t}$. This shows that students still understand that velocity is a position per unit of time [17][20], not a change of position at time interval [23]. The findings show that many students are still having trouble with measuring the distance through the velocity-time graph. Students' ability to interpret the area under tha graph usually became the reason why students difficult to answering this type of question.

Based on the pattern formed, students are different by their level of student understanding. Students' level of understanding are devided into three (see Table 6).

Table 6. Students' level of understanding based on their responses

No	Categories	Level of understanding	Total of students
1	Correct answer-correct reason	Sound understanding [SU]	26%
2	Correct answer-incorrect reason	Misconception [M]	6%
3	Incorrect answer-incorrect reason	No understanding [NU]	68%

From all of students respond to the questions, most students have low ability in interpreting graphs. Among the many skills could be delveloped in physics learning, one of this skills should be emphasize, namely the ability to interpret graphs. A graph is one of the representation that always used in physics problem. From the graph, students should able to choose informative feature in order to solve problem. Therefore, by studying the challenges and obstacles that students experience is that teachers may be able to develop better and more productive learning environments [30].

4 Conclusion

According to the evaluation of physics students' conceptual understanding, it was discovered that students were still having trouble differentiating between the different kinds of motion of the objects shown in the s-t, v-t, and a-t graphs. In addition, only some students can read the data from the graph to determine the distance of objects. The problem is caused by a lack of understanding of kinematics concepts, particularly those related to acceleration, displacement, velocity, and distance. Students are not able to identify the difference between s-t and v-t graphs. In summary, the level of student's understanding of kinematics reached 26% of SU, 6% of M, and 68% of NU. The teacher must be able to design the right strategy to teach kinematics concepts easily to students. One of them can use recitation, which can remediate students' misconceptions.

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